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Distribution of juvenile cephalopods collected during a survey on tuna larvae in the Mediterranean Sea (1994)

Gian Maria Balducci* (✉) & Corrado Piccinetti#

* Società Cooperativa Progetto Blu, (C.I.R.S.PE, Centro Italiano Ricerche e Studi per la Pesca), Strada Nazionale Adriatica Sud, 44/8, 61032 Fano (PU), Italy, gbalducci@progettoblu.it (✉) Corresponding Author

Dipartimento di Biologia Evoluzionistica Sperimentale, Università degli Studi di Bologna, Laboratorio Biologia Marina e Pesca di Fano, V.le Adriatico 1/N, 61032 Fano (PU), Italy, cpiccinetti@mobilia.it

Abstract

Plankton samples were collected during a survey on tuna larvae carried out throughout the Mediterranean Sea from the 7July to the 5 August 1994. Two double oblique hauls, with a BONGO 60 plankton net and a FAO plankton net, were carried out in 302 stations. The examination of the BONGO collected samples revealed 542 juvenile cephalopod specimens of 14 different species. Results showed that juvenile cephalopods are a significant part of the zooplankton in the epipelagic stratum of the Mediterranean Sea. They are represented mostly by members of the families Onychoteuthidae and Enoploteuthidae. Juveniles of *Chtenopteryx sicula* were also abundantly collected.

Riassunto

Il Laboratorio di Biologia Marina e Pesca di Fano, nell'ambito della Commissione Internazionale per la Conservazione dei Tunnidi dell'Atlantico e del Mediterraneo (ICCAT), ha condotto una campagna di pesca sperimentale in 302 stazioni, utilizzando due retini per plancton, BONGO 60 e FAO. Le stazioni, distribuite su tutta l'area mediterranea, erano distanti fra loro 15 miglia nautiche. I prelievi, svolti sia nelle ore diurne che in quelle notturne, hanno interessato il bacino orientale, nel periodo dal 17/6/94 al 7/7/94 (stazioni 1-116), e quello occidentale, dal 23/7/94 al 5/8/94 (stazioni 140-302). Le pescate sono state effettuate in doppio obliquo, raggiungendo una profondità media di 70 m. Per ogni campione, sono stati separati gli stadi giovanili dei cefalopodi dal resto del plancton. L'identificazione si è basata soprattutto sull'analisi morfologica ed ha preso in esame esclusivamente il materiale raccolto dal BONGO 60. In tutto sono stati catturati 542 giovani planctonici, per 115 dei quali non è stata possibile l'identificazione a livello specifico. Sono state individuate 14 specie. Le modalità con cui sono state eseguite le pescate non consentono un'analisi precisa dei ritrovamenti in base alla profondità. Dalla suddivisione in fasce orarie delle pescate effettuate durante la campagna è emerso che una componente significativa delle catture è stata registrata nelle ore notturne. Tenendo conto della profondità media raggiunta dal retino, si può supporre che i giovani cefalopodi risiedano a profondità maggiori nelle ore diurne portandosi verso la superficie durante la notte. Nella regione epipelagica del Mediterraneo, lungo i punti presi in esame dalla campagna, i giovani cefalopodi costituiscono una componente significativa dello zooplancton, e fra essi si nota una predominanza di Onicoteutidi e di Enoploteutidi ai quali si deve aggiungere la presenza massiccia di giovani di *Chtenopteryx sicula* finora non evidenziata in letteratura.

Key words

Juvenile stages, Cephalopoda, Mediterranean, plankton, distribution.

Introduction

Juvenile cephalopods play an important role in the feeding relation and in the trophic web of the pelagic marine ecosystem (Amaratunga, 1983). However, young forms are still not known for many species and the identification of young stages often does not reach the desired taxonomic level (Sweeney et al., 1992).

Juvenile cephalopods show many features that are not present in adult stage (Okutani, 1987): compared to adults they have different body proportions, a different mantle shape, often with rudimental fins and different body chromatophores pattern. Young stages of many species have stalked eyes and quite often a different number of photophores than in the adult phase. However, these characteristics are very useful for juvenile identification (Okutani, 1987).

The post-hatching cephalopods growth has been analysed by many authors and one of the important controversies concerns the validity of the term "larva" and whether the very young cephalopods may be defined "larvae". Indeed as for the cephalopods this definition is not completely right because their metamorphosis does not pass through a second stage (Boletzky, 1974).

Old studies on specimens collected in the Mediterranean Sea are useful to the identification of the juvenile stages of some species (Naef, 1923; Issel, 1920a, b, 1925; Degner, 1925; Sanzo, 1929). Roper (1974) gave an important contribution to the knowledge of vertical and seasonal distribution of pelagic cephalopods in the Mediterranean Sea. A survey followed by the collection of juvenile cephalopods was carried out by Sanchez and Molí (1985) along the Mediterranean coast of Spain, and three more recent surveys have been carried out in the Aegen Sea (Lefkaditou et al., 1999 and 2005; Salman et al., 2003).

All these studies gave a precious contribution to the knowledge on the ecology, distribution and identification of young cephalopods in the Mediterranean Sea. However, these studies took into consideration a limited area. Following the survey carried out by Roper (1974),

which took into consideration adult specimens too, no other plankton survey throughout the whole Mediterranean basin is reported in the scientific literature.
The aim of this paper is to contribute to the knowledge of the distribution of juvenile cephalopods in the Mediterranean Sea, with the identification of many young cephalopods stages collected during an ICCAT international research survey on tuna larvae carried out by the Fano Marine Biology Laboratory. The objective of the ICCAT plankton survey was to determine the distribution and the abundance of tuna larvae in this basin. The expedition provided an occasion to examine the plankton samples collected in 302 stations distributed in the whole Mediterranean Sea, in the summer of 1994. The survey has investigated mainly the epipelagic water layer. With this study we aimed to examine the presence of young cephalopods in this area according to the different light conditions of a 24-hour period.

Material and methods

The juvenile cephalopods were collected in the summer of 1994, from the 17 June to the 5 August, during an international research survey on tuna larvae carried out in the Mediterranean Sea.
The research was carried out by two vessels, the Italian Copernaut "Franca" and the Japanese Soyu Maru, along the Mediterranean area, in pre-established 302 stations 15 miles apart of one another. In each point two double oblique hauls, the first one with a BONGO 60 plankton net and the second one with a FAO plankton net, were carried out. The bongo 60 plankton net is composed of two 60 cm diameter mouths fitted with 335 µ and 505 µ mesh nets respectively; the FAO plankton net has a single 100 cm diameter mouth fitted with a 505 µ net.
In this study we took into consideration all the samples collected by the BONGO 60 by the Italian vessel. This vessel worked continuously during the survey period, that is day and night; therefore the hauls were carried out with different light conditions, during daytime, at sunset, at night and at sunrise (**Tab. 1**). The collected samples were separated into three different light interval: from 8 am to 6 pm (high light intensity), from 8 pm to 6 am (low light intensity), from 6 am to 8 am and from 6 pm to 8 pm (intermediate light intensity) (**Tab. 1**).
In a specific area of the Ionian Sea, "inter-calibration zone" in order to calibrate the collected data by the two vessels, 22 hauls (station nos. 117 to 139) were carried out simultaneously by both vessels, from the 19 July to the 20 July.
From the 17 June to the 7 July, the Italian vessel worked in the eastern Mediterranean basin, from the 23 July to the 5 August, in the western basin. The data collected in the intercalibration-zone were pooled to those of the east side for their quantitative assessment.
During the survey, the hydrological parameters salinity and oxygen level were sampled by the Idronaut probe.
In each station, the plankton nets were double-towed obliquely between the surface and the depth of 70-80 m. Each net was equipped with a mechanical flow-metre to record the volume of filtered water and a depth-finder to estimate the tow depth. Through the combination between the volume of water filtered and the maximum depth reached in each haul it is possible to evaluate the number of juveniles collected per unit surface (m^2). For a best representation of data we have multiplied the results by 1,000 and we have showed the richness as N specimens/1,000 m^2.
All samples were fixed and preserved in 5% seawater formalin for the subsequent laboratory processing. Sample analysis and juvenile cephalopod identification was carried out with an optical microscope. Each preserved specimen was measured (dorsal mantle length, ML).
The species were identified according to Issel (1920 a, b, 1925), Naef (1923) and the key in the manual for "larval" and juvenile cephalopods identification (Sweeney, 1992).

Results

Juvenile cephalopods were caught in 194 stations, i.e. 64% of the total stations. In these stations, in all 542 young cephalopods were caught.
The identification of 115 specimens was impossible, either because they were too damaged during the haul or badly preserved, or because of their too early development stage.
The sampling depth was in between 38 and 140 m; anyway most of the hauls were carried out in the depth range from 60 to 100 m. The bongo 60 reached the depth of 100 m or deeper in 50 stations.
The low light positive stations are included in the 70-90 m depth range. The net reached a depth deeper than 100 m in 7 night positive hauls and in 14 positive daytime

Mediterranean zone	Period	N of stations	N of station at each light intensity interval		
			High	Intermediate	Low
East	17.6.94 – 7.7.94	116	51	20	45
Inter-calibration	19.7.94 – 20.7.94	23	3	7	13
West	23.7.94 – 5.8.94	163	64	28	71
Overall	17.6.94 – 5.8.94	302	118	55	129

Tab. 1. Number of stations sampled during the survey period in each area and in each light interval.

Tab. 1. Numero di stazioni campionate e periodo di campionamento in ciascuna area ed in ciascuna condizione di luce.

stations. However, oblique tows do not give an accurate information on the depth of catches.

The number of positive stations in the three different light conditions is shown in **Fig. 1.**

The highest number of positive stations is in the low light interval: 93 positive stations for young cephalopods out of 129 sampled stations.

The following percentages of collected juveniles cephalopods are: 53% caught during the night, 30% in the day light, and 17% with intermediate light conditions (**Fig. 2**). **Tab. 1** reports the total number of juveniles caught in each light interval; 287 young specimens were collected at night. However the number of hauls carried out in each light interval is different and the majority of hauls were carried out at night. We tested such data by the Pearson's χ^2-test to verify the significance, if any, of this difference. The χ^2-test showed that there is no causal relation between intensity of light and the probability to catch young cephalopods ($P > 0.05$); on the contrary, it appears that the intensity of light has an influence on the number of juveniles caught ($P < 0.001$).

Moreover, three different intervals of richness have been identified: 1) 50 ≤ N specimens/1000 m² ≤ 200; 2) 200 ≤ N specimens/1000 m² ≤ 700; 3) N specimens/1000 m² > 700.

The maps in **Figs. 3** to **11** show the distribution of the collected species (positive stations along the sampling grid). In the maps, the respective richness interval for each station, regarding the most abundant species, is shown.

In **Fig. 3** the richness distribution (juvenile cephalopods/1000 m²) along the sampling grid according to the three interval pre-established is shown.

According to the data presented in **Tab. 2**, a larger quantity of young cephalopods was collected in the eastern basin. In this basin there are 15 stations with the richness in the highest interval, 12 of which are in the Ionian Sea, whereas in the western basin such a richness is reached

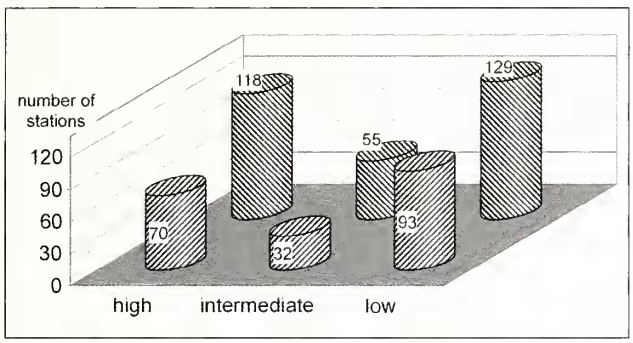

Fig. 1. Number of positive tows/total number of tows carried out in each light interval.

Fig. 1. Numero di cale positive/numero totale di cale effettuate in ciascuna condizione di luce.

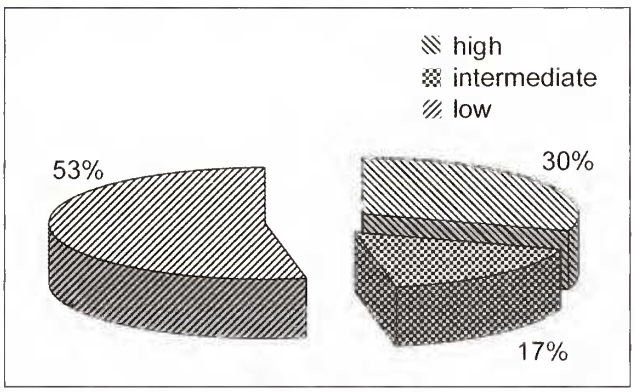

Fig. 2. Percentage of catches accomplished in each light interval.

Fig. 2. Percentuale di catture realizzate in ciascuna condizione di luce.

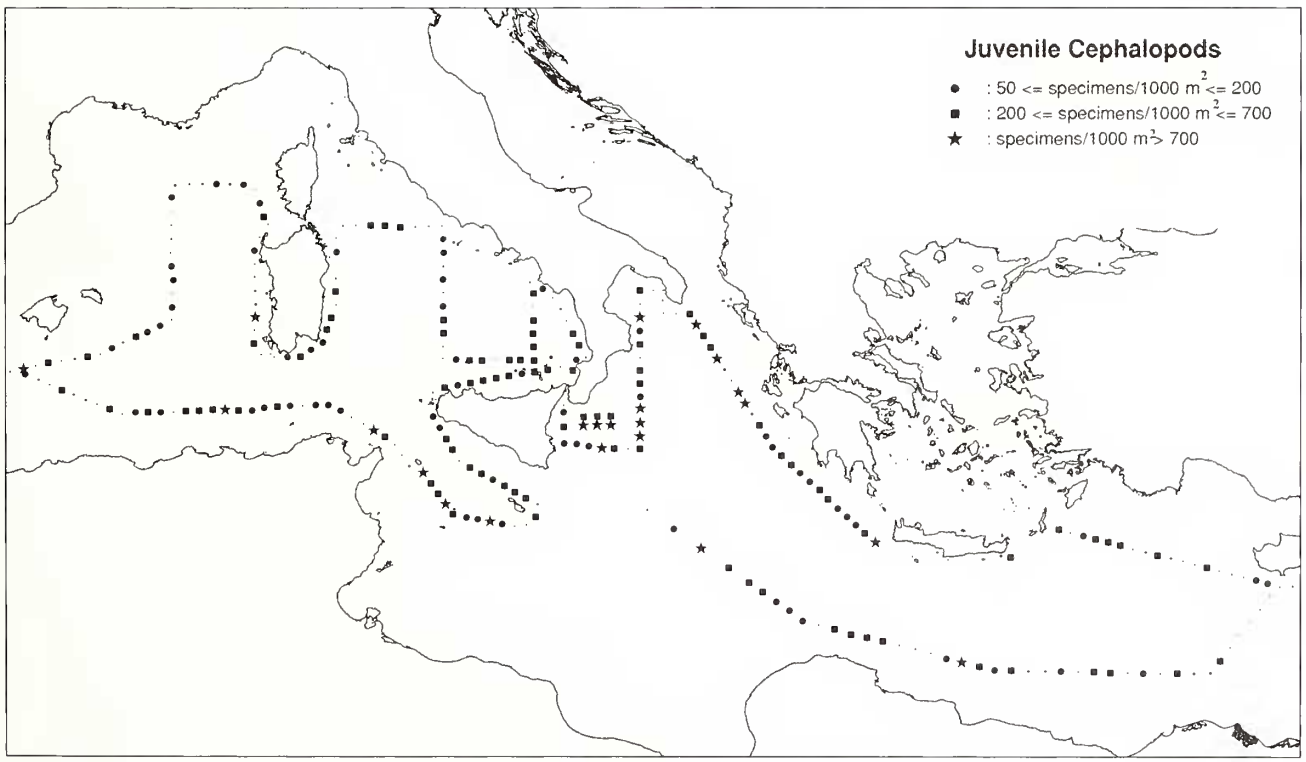

Fig. 3. Abundance (specimens/1000 m²) of total juvenile cephalopods collected along the sampling grid.

Fig. 3. Abbondanza complessiva (esemplari/1000 m²) dei giovanili di cefalopodi raccolti lungo la griglia di campionamento.

only in 7 stations. As regards the West Mediterranean, we have recorded the highest number of catches in the Sicily Channel and in the southern Tyrrhenian between the Ustica island and the Aeolian Archipelago. The lowest quantity of catches was recorded in the stations in the north-western side of the basin.

Species	N	Mediterranean area		Light intensity			ML range
		West	East	interm.	high	low	mm
Heteroteuthis dispar (Rüppell, 1844)	12	11	1	–	–	12	3-5
Ancistrocheirus lesueuri (d'Orbigny, 1842)	3	2	1	–	1	2	5-9
Enoploteuthidae spp.	75	34	41	18	22	35	1.6-8
Brachioteuthis riisei (Steenstrup, 1882)	18	4	14	–	4	14	1.2-15
Chiroteuthis veranii (Férussac, 1835)	3	1	2	–	1	2	8-35
Galiteuthis armata Joubin, 1898	6	–	6	2	3	1	3.6-8
Chtenopteryx sicula (Vérany, 1851)	106	16	90	20	29	57	1.2-6
Octopoteuthis sicula Rüppell, 1844	36	27	9	18	1	17	1-3.6
Ommastrephidae spp.	27	18	9	2	6	19	1.2-4.4
Onychoteuthidae spp.	111	68	43	6	41	64	1.8-6
Thysanoteuthis rhombus Troschel, 1857	6	–	6	1	4	1	2.8-8
Octopus defilippi Vérany, 1851	1	1	–	–	1	–	2.8
Octopus vulgaris Cuvìer, 1797	11	7	4	1	6	4	1.2-3.2
Scaeurgus unicirrhus (Delle Chiaje, 1840)	12	6	6	1	5	6	1-3.6
Unidentified	115	44	71	24	38	53	–
Total cephalopods	542	239	303	93	162	287	–

Tab. 2. Cephalopod species, number of individuals collected per species in the two Mediterranean basins and in each light intervals, and their size ranges.

Tab. 2. Specie di cefalopodi, numero di individui raccolti per specie nei due bacini mediterranei in ciascuna condizione di luce e loro taglie.

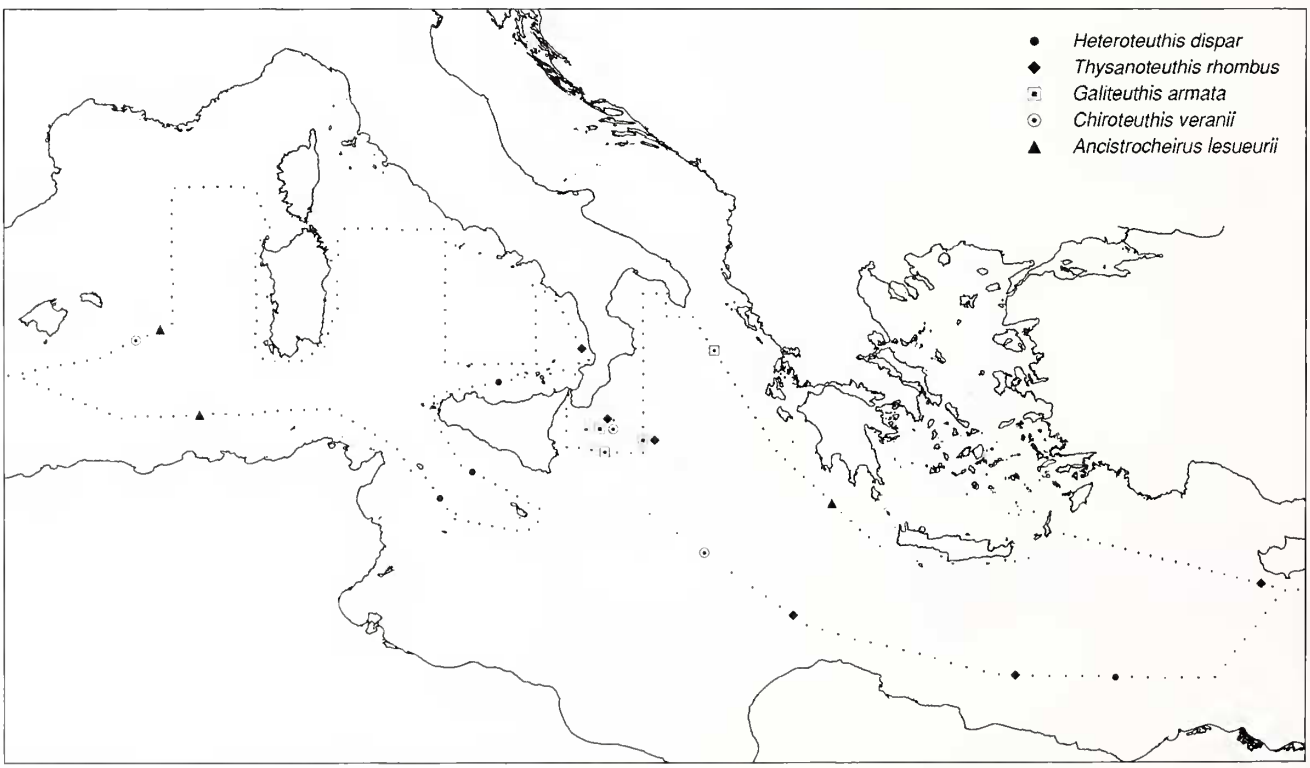

Fig. 4. Distribution of *Heteroteuthis dispar* and most rare species: *Thysanoteuthis rhombus*, *Galiteuthis armata*, *Ancistrocheirus lesueurii*, and *Chiroteuthis veranii*.

Fig. 4. Distribuzione di *Heteroteuthis dispar* e delle specie più rare: *Thysanoteuthis rhombus*, *Galiteuthis armata*, *Ancistrocheirus lesueurii* e *Chiroteuthis veranii*.

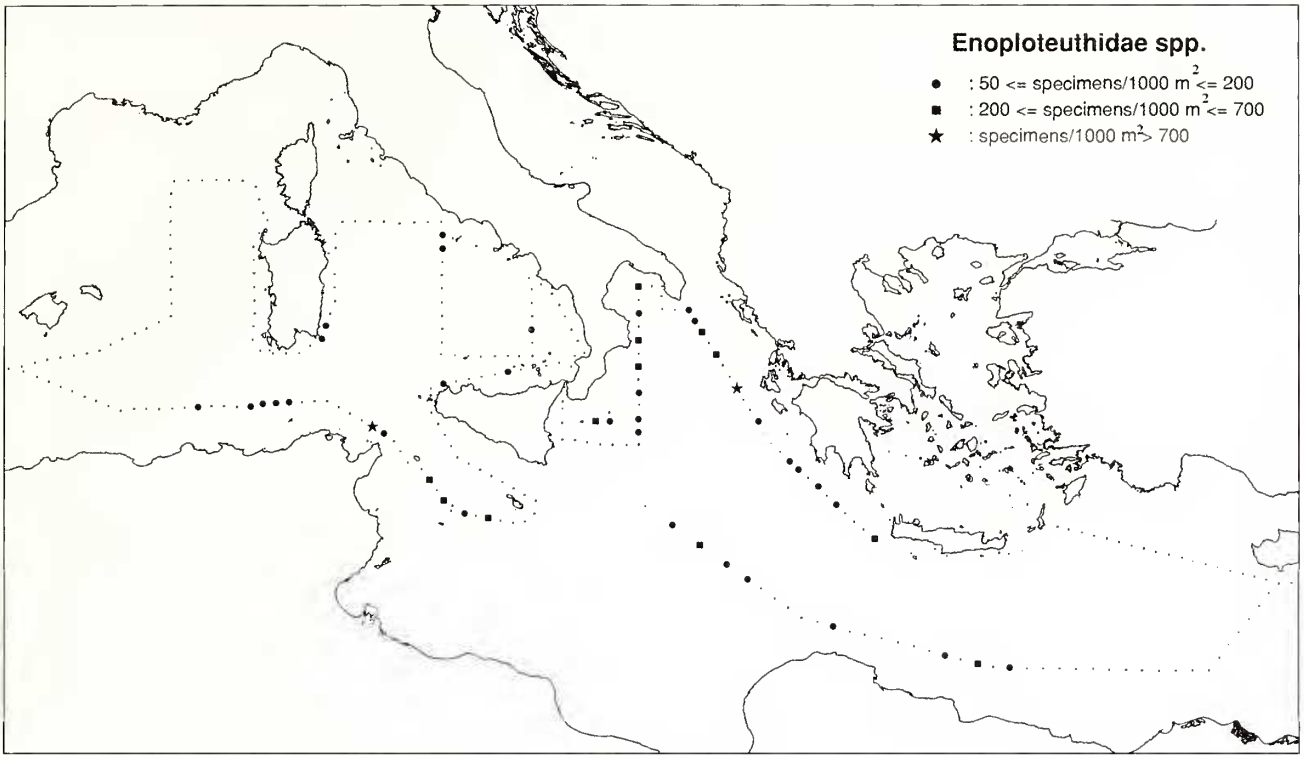

Fig. 5. Distribution and abundance (specimens/1000m^2) of Enoploteuthidae spp.

Fig. 5. Distribuzione e abbondanza (esemplari/1000m^2) di Enoploteuthidae spp.

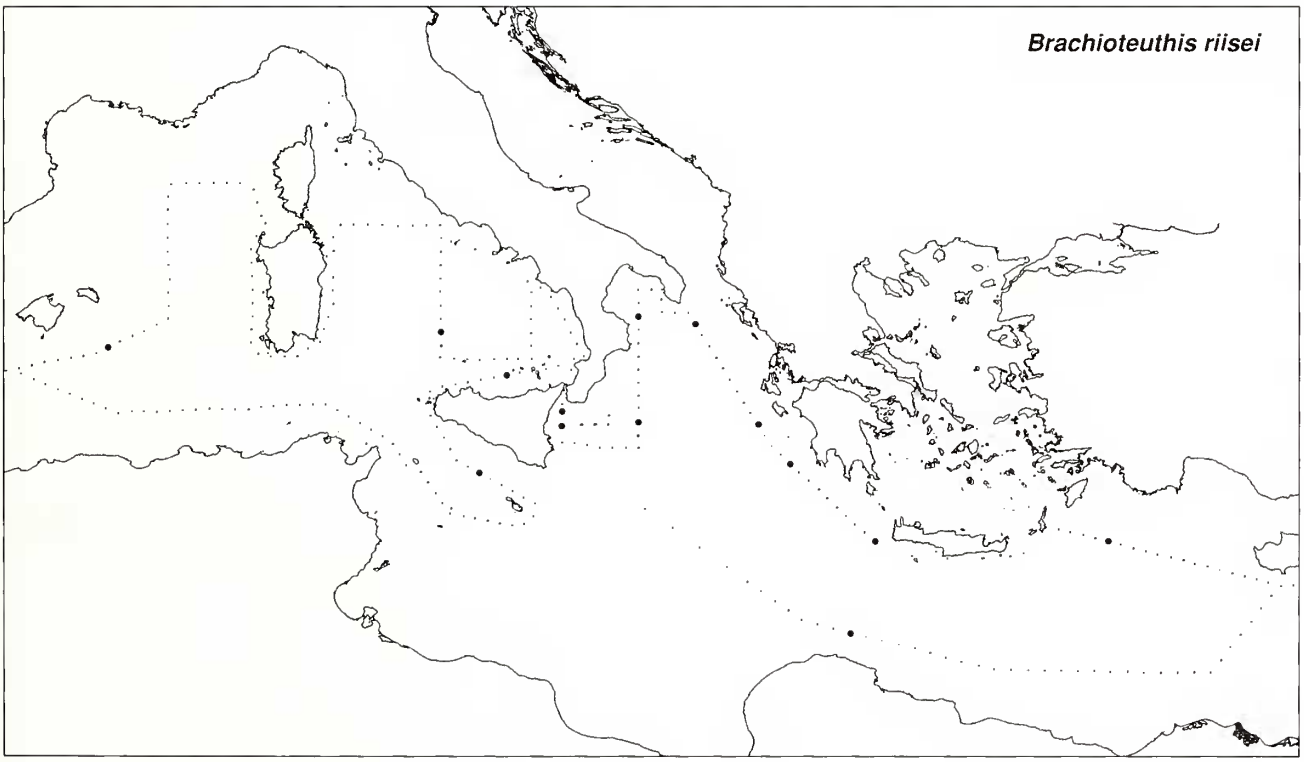

Fig. 6. Distribution of *Brachioteuthis riisei*.

Fig. 6. Distribuzione di *Brachioteuthis riisei*.

The table shows the species collected and the number of specimens belonging to each species, their size (ML), the area of captures and the relative light intensity during the hauls. It appears that the majority of specimens were caught at night. However, juveniles of the most abundant species (Enoploteuthidae spp., Onychoteuthidae spp., and *Chtenopteryx sicula*) were also collected abundantly in other light interval.

The quantitative data for all the collected species are shown in **Tab. 2**.

The following species deserve a more detailed analysis.

Family Enoploteuthidae

In the Mediterranean Sea, this family is represented by two species (Mangold & Boletzky, 1987): *Abralia veranyi* (Rüppell, 1844) and *Abraliopsis morisii* (Verany, 1839). We found 75 specimens belonging to this family, 41 of which collected in the East Mediterranean and 34 in the West Mediterranean. In the east side of the basin the catches are rather uniformly distributed, except the area between the Island of Crete and Cyprus. We found some specimens in the western basin along the west coasts of Sardinia, in the Tyrrhenian Sea and along the Tunisian coasts (**Fig. 5**). Most collected specimens were too little (1.6 to 6 mm ML) to allow any identification to the species level; the only specimen large enough to be identified (8 mm ML) was in a bad state of preservation.

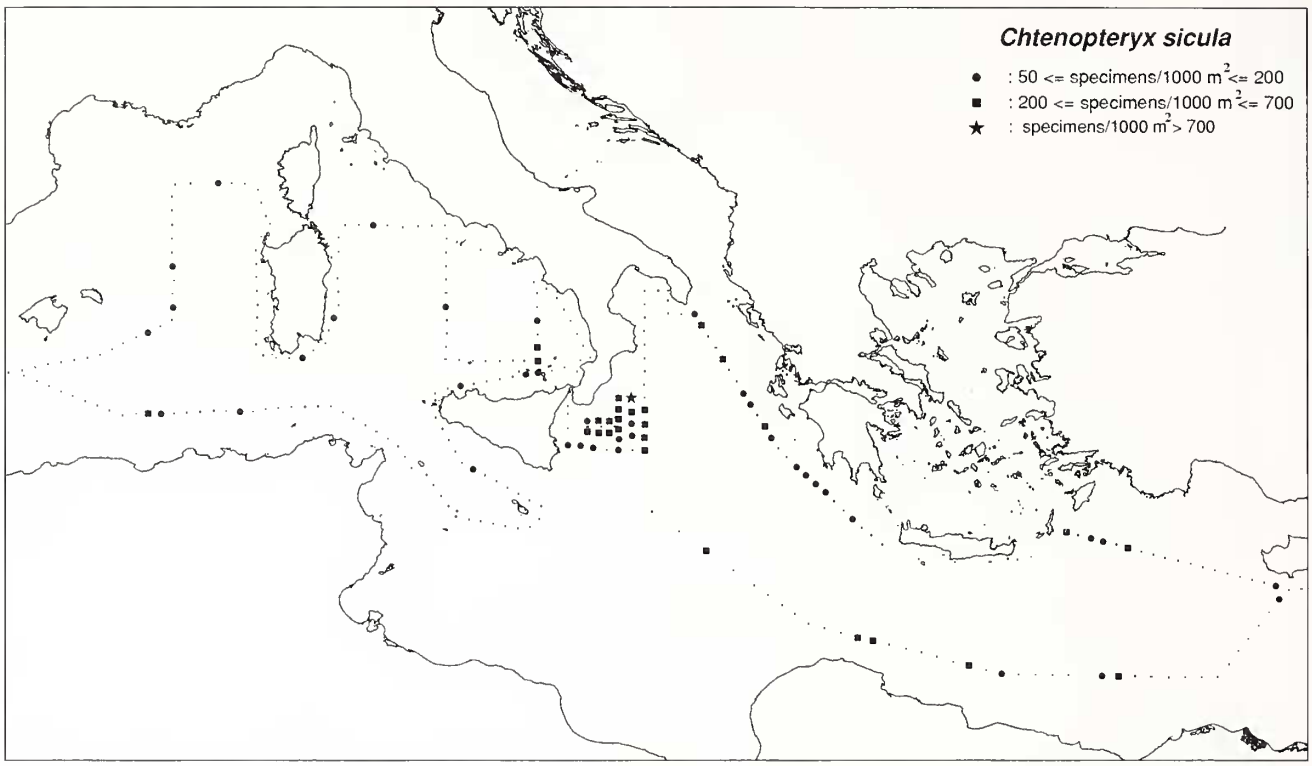

Fig. 7. Distribution and abundance (specimens/1000m²) of *Chtenopteryx sicula*.

Fig. 7. Distribuzione e abbondanza (esemplari/1000m²) di *Chtenopteryx sicula*.

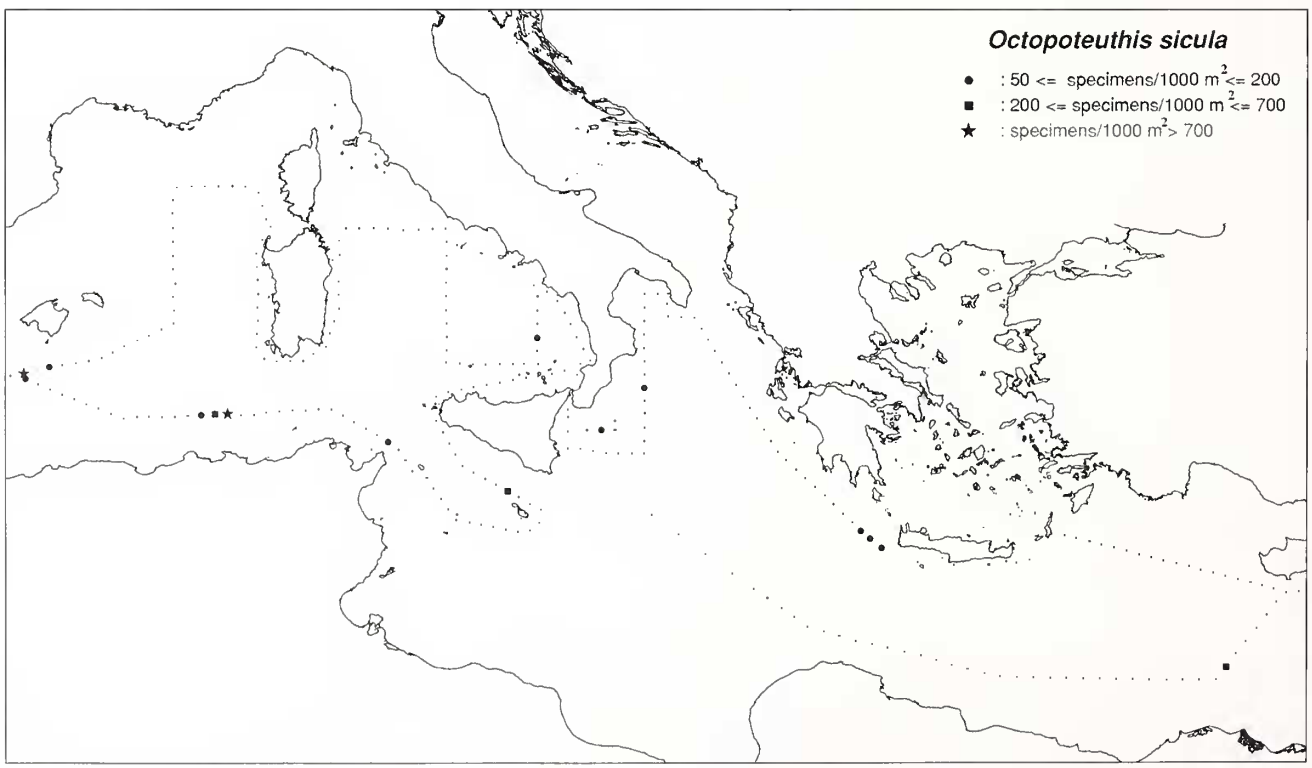

Fig. 8. Distribution and abundance (specimens/1000m²) of *Octopoteuthis sicula*.

Fig. 8. Distribuzione e abbondanza (esemplari/1000m²) di *Octopoteuthis sicula*.

Family Ommastrephidae

The early juvenile stage of this family was named *Rhyucoteuthis* by Chun (Naef, 1923). In the Mediterranean Sea, this family is represented by four species (Bello, 2003): *Ommastrephes bartramii* (Lesueur, 1821), *Illex coindetii* (Vérany, 1839), *Todaropsis eblanae* (Ball, 1841), and *Todarodes sagittatus* (Lamarck, 1798). The *Rhyucoteuthis* is easily recognizable from juvenile cephalopods of other families, but it is very difficult to distinguish between the young stages of the different ommstrephid species before they reach an advanced stage (Naef, 1923). We found 18 specimens in the west side of the basin and 9 in the east, all of them between 1.2 and 4.4 mm ML (**Fig. 9**).

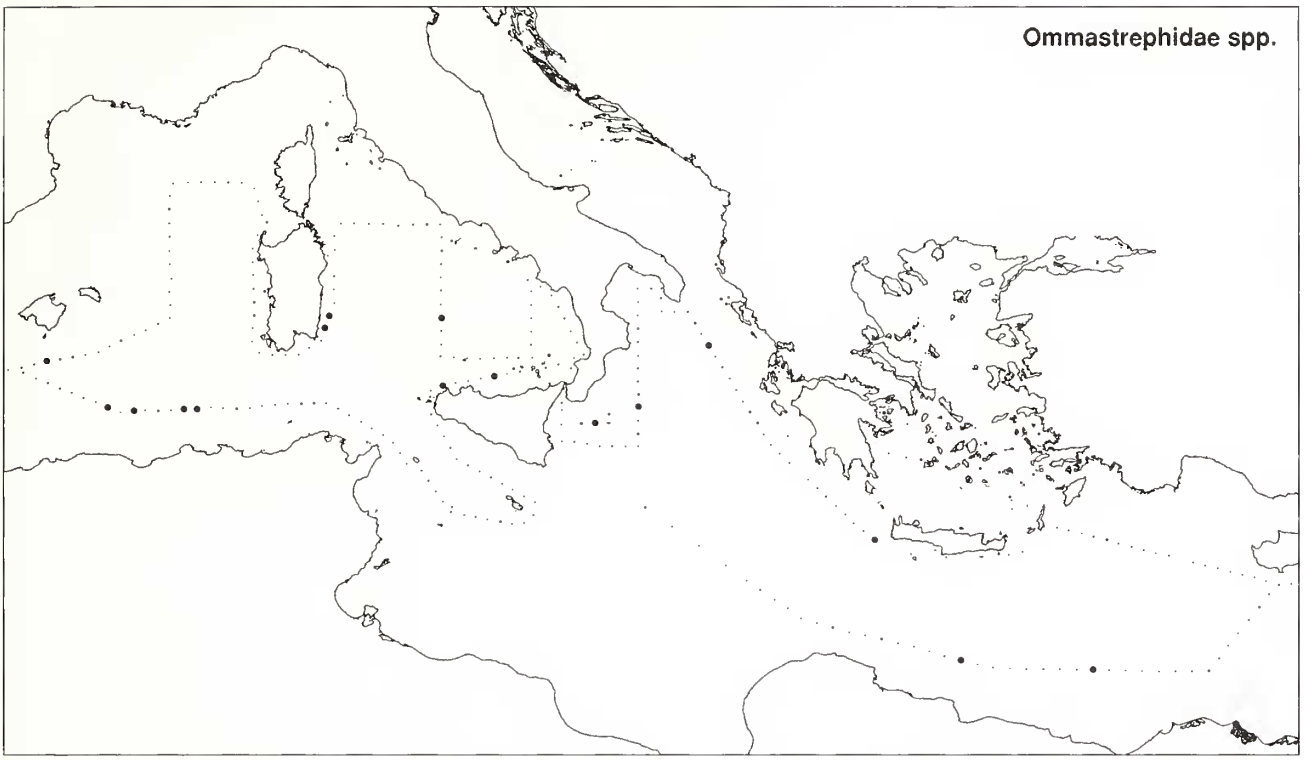

Fig. 9. Distribution of Ommastrephidae spp.

Fig. 9. Distribuzione di Ommastrephidae spp.

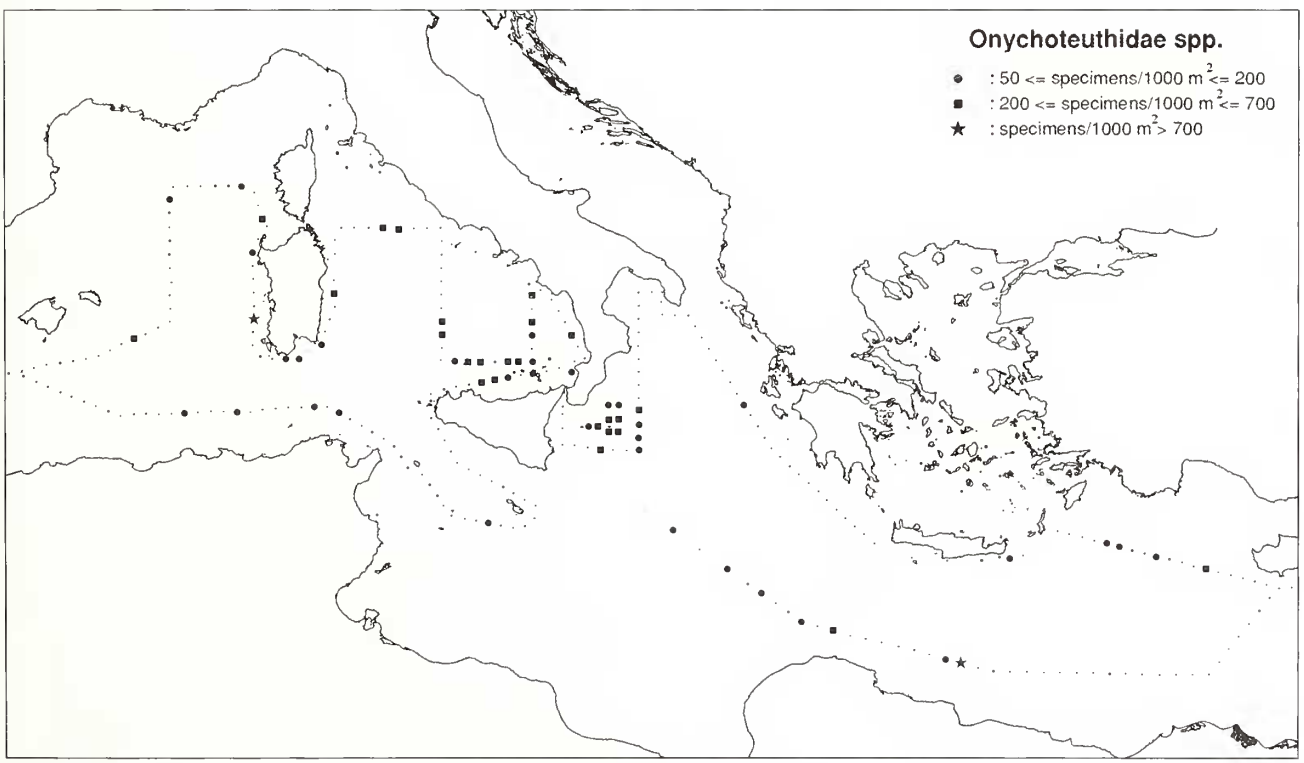

Fig. 10. Distribution and abundance (specimens/1000m^2) of Onychoteuthidae spp.

Fig. 10. Distribuzione e abbondanza (esemplari/1000m^2) di Onychoteuthidae spp.

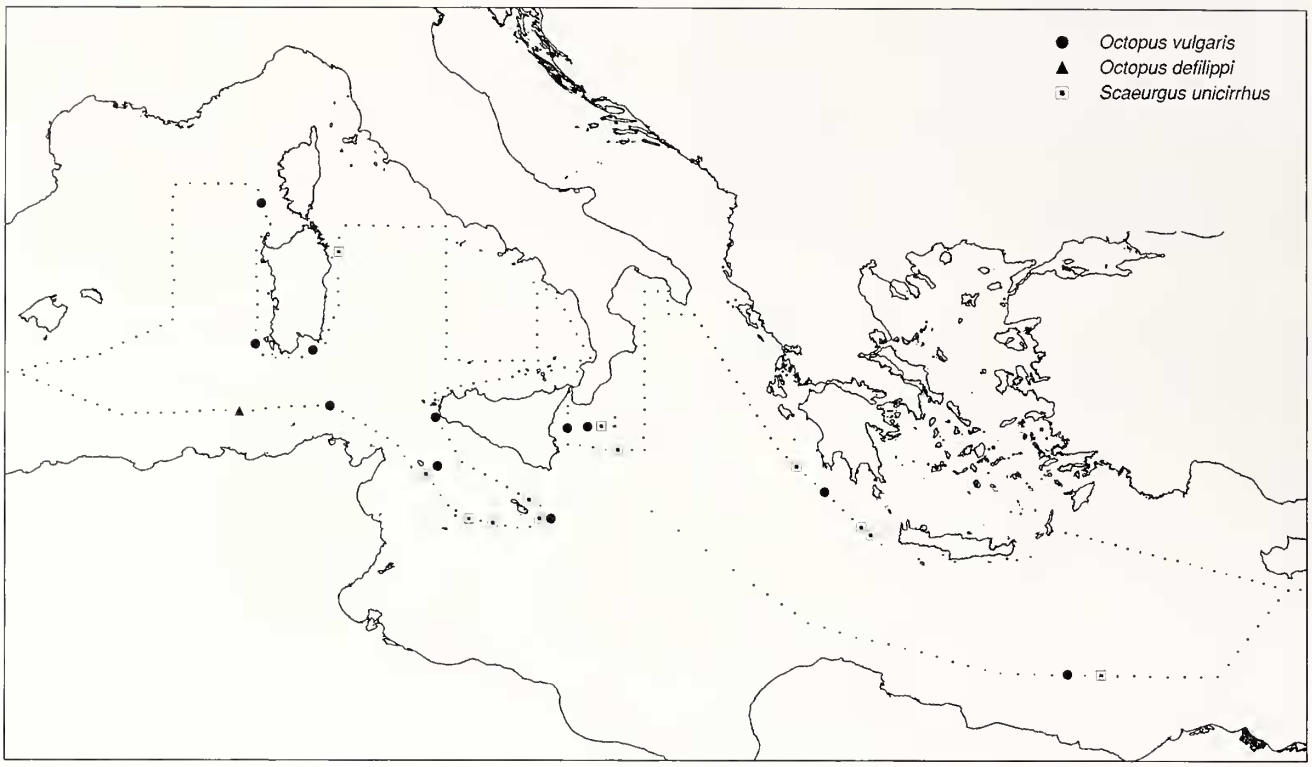

Fig. 11. Distribution of Octopoda.

Fig. 11. Distribuzione di Octopoda.

Family Onychoteuthidae

In the Mediterranean Sea, this family is represented by two species (Mangold & Boletzky, 1987): *Ancistroteuthis lichtensteinii* (Férussac, 1835) and *Onychoteuthis banksii* (Leach, 1817). All the collected specimens have a size between 1.8 e 6 mm ML, whereas species identification is possible only for specimens larger than 11 mm ML (Sweeney et al., 1992). The specimens belonging to this family make up the largest fraction of juvenile cephalopods collected in the survey. We netted 68 specimens in the west side of the basin and 43 in the east, distributed in 60 stations (**Fig. 10**).

Discussion

According to the results, we can state that juvenile cephalopods are quite common in the epipelagic zone of the Mediterranean where they occur throughout the 24 hours.

They are more abundant in the night hours, in accordance with the nictemeral cycles described for adults and juvenile stages (Young et al., 1985): according to the results of many authors on vertical distribution, young cephalopod ascend at night towards the sea surface (e.g. Lefkaditou et al., 2005).

Oblique tows do not give any information on the vertical distribution of collected specimens; hence a detailed review of catches according to depth is not possible.

The relatively small size of juveniles caught might suggest that the areas of distribution reported coincides with the spawning areas, but the spawning habits of Teuthoids, i.e. the majority of collected specimens, does not allow any highly detailed information.

The richness of juvenile cephalopods is higher in areas that are generally known as strategic for many Mediterranean species: the Ionian Sea between the Sicilian and Calabrian coasts and in the Sicily Channel, according to data that show how cephalopods take advantage of high biological productivity and hydrographic regimes that achieve a fast growth during their short life span (Lefkaditou et al., 1999).

We can state that the species of Onychoteuthidae spawn in the summer in all the Mediterranean basin, particularly in the Ionian Sea, and their juvenile stages follow the adult mode of life and are concentrated in the upper 100 m of depth (Roper, 1974).

The results obtained for *Chtenopteryx sicula* suggest that this species spawns in this part of the year in all the Mediterranean and prefers central-southern waters; moreover, their juvenile stages too follow the adult mode of life and are concentrated in the upper layers (Roper, 1974).

The Enoploteuthidae appear to prefer the central-eastern and south-western areas.

Octopoteuthis sicula and *Brachioteuthis riisei* (**Fig. 12C**) have shown a spot distribution along the sampling grid. The same situation has been observed for the Ommastrephidae, which are absent from the southern areas.

Juvenile stages of *Heteroteuthis dispar* were found in only 4 stations, 1 in the East Mediterranean and 3 in the West Mediterranean. Issel (1925) believes this sepiolid to be a neritic species but recent studies have shown a wide distribution in open waters at high depth (Roper, 1974). The specimens of *Heteroteuthis dispar* were caught only at

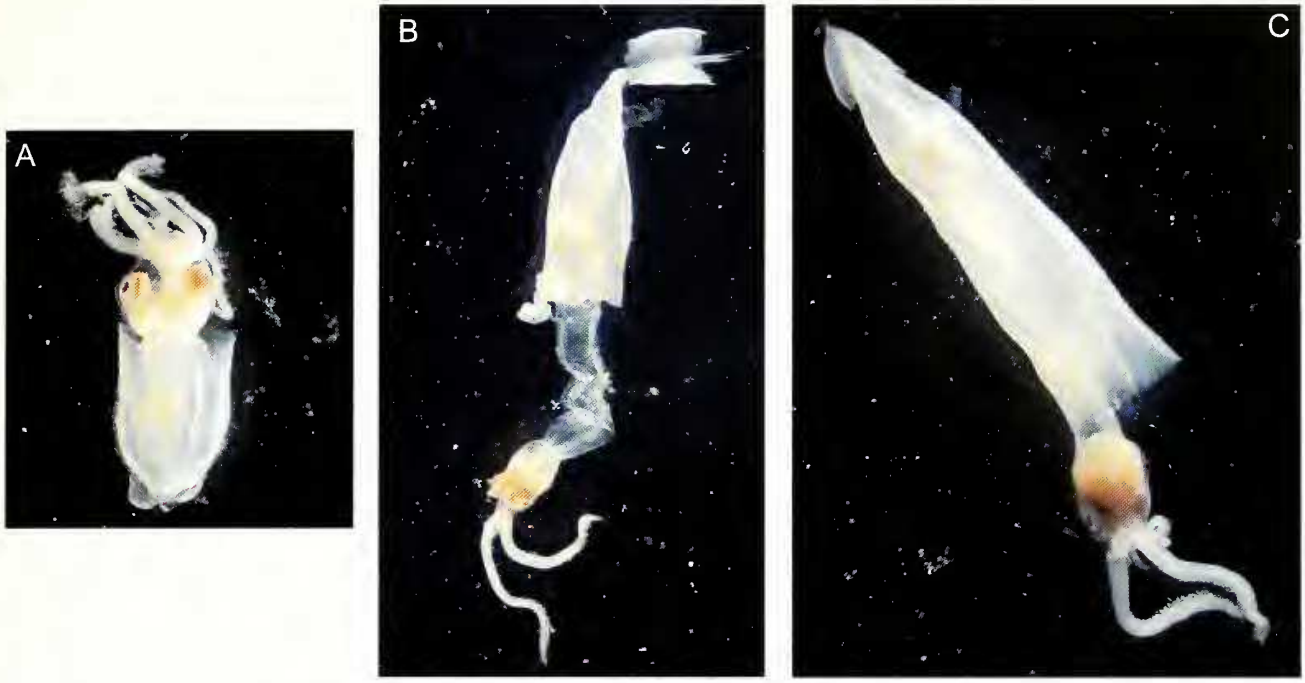

Fig. 12. "Larval" stages. **A**. *Ancistrocheirus lesueurii* (7 mm DML), West Mediterranean, st. no. 221. **B**. *Chiroteuthis veranii* (8 mm DML), West Mediterranean, st. no. 223. **C**. *Brachioteuthis riisei* (15 mm DML), West Mediterranean, st. no. 298.

Fig. 12. Stadi "larvali". **A**. *Ancistrocheirus lesueurii* (7 mm LMD), Mediterraneo occidentale, staz. 221. **B**. *Chiroteuthis veranii* (8 mm LMD), Mediterraneo occidentale, staz. 223. **C**. *Brachioteuthis risei* (15 mm LMD), Mediterraneo occidentale, staz. 298.

night, when they shift up toward the surface (Roper, 1974).

The most rarely caught species, namely *Thysanoteuthis rhombus*, *Galiteuthis armata*, *Ancistrocheirus lesueurii*, and *Chiroteuthis veranii*, were collected in a small number of specimens (**Fig. 12**).

We can lastly state that in the epipelagic layer of the Mediterranean Sea juvenile cephalopods are a significant part of the zooplankton. They are represented above all by the Onychoteuthidae and Enoploteuthidae, in accordance with the information reported by Issel (1925). Moreover, we have to point out the abundant presence of juveniles of *Chtenopteryx sicula*.

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